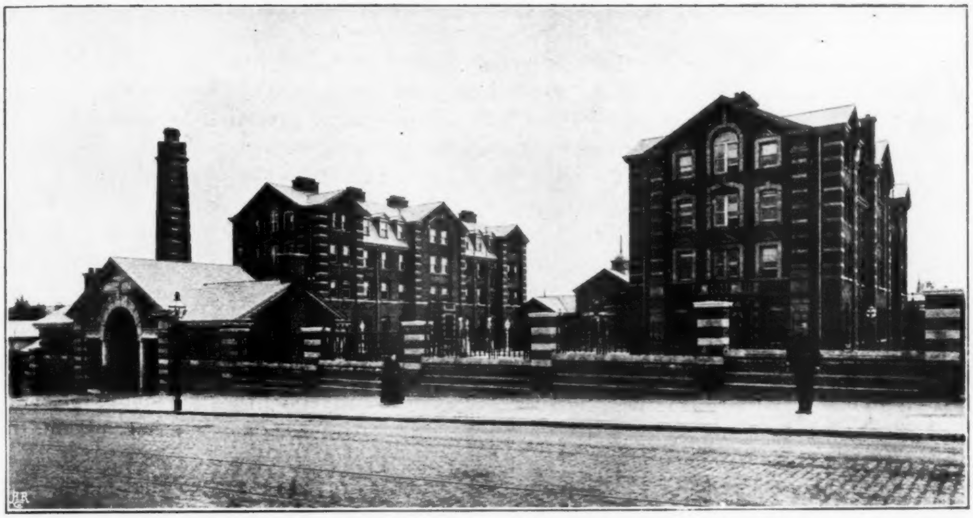


FIG. 1—ROYAL VICTORIA HOSPITAL, BELFAST: VIEW FROM THE NORTH-WEST.

ROYAL VICTORIA HOSPITAL, BELFAST: ITS INITIATION, DESIGN, AND EQUIPMENT.

By WILLIAM HENMAN [*F.*] and HENRY LEA, M.Inst.C.E.

I. By WILLIAM HENMAN.

I VENTURE to appear before you this evening, trusting that some particulars of the Royal Victoria Hospital, which was opened by their Majesties the King and Queen when they visited Belfast on the 27th of July this year, may be of value to those interested in hospital development.

There is much that is unique in its inception, original in its design, and novel in its equipment which has naturally attracted attention to this hospital; but being located in the Sister Isle it is not easily accessible to all who may desire to understand it, and therefore it appears to be advisable that an authentic description should be published of the reasons which led up to what has been termed a "revolution in hospital design," as well as of the methods and means by which it has been accomplished.

Incorrect description or misapprehension of what prompted so radical a change in plan is liable to prejudice improperly those who fail to realise the objects aimed at. The tendency is to follow beaten tracks, and only those who have good reasons for departing therefrom should venture to cut out a path for themselves; but having done so, they alone are able to describe what was observed and encountered by the way; consequently it may depend upon the ability of observation and power of description exercised by pioneers whether a new way may become a beaten track or will remain neglected.

Independent action doubtless has its dangers, and frequently arouses alarm in the minds of those simply content to follow in the footsteps of others—never venturing to question whether there may not be a better course to pursue.

I make these remarks because since the buildings have been seen in their completed condition surprise has been expressed at their internal airy cheerfulness, several visitors

having remarked that believing them to be only lighted by "skylights," none of which could be opened, they expected to find the wards dreary and stuffy. Prejudiced as they were by imperfect and incorrect description, some had evidently come expecting to condemn, but I have good reason to believe that none went away failing to approve.

Although I cannot show you the actual buildings, by an inspection of which you would be the better able to judge as to their merits in the directions aimed at, yet by the aid of drawings and photographs, together with some explanation, you may, I hope, realise that even if the plan is revolutionary in its tendency, it is no unreasoned fad, but a serious endeavour to simplify and, if possible, improve hospital design.

Whether it is destined to secure permanent approval or be pointed at as an example to be avoided depends--first, whether the essentials in hospital design have been properly appreciated and applied; secondly, whether those having the care and management of the institution will maintain it in efficiency—for it must be remembered that the more perfect an instrument is for accurate and effective work the more worthy it is of careful upkeep, and the more easily it may be rendered faulty by neglect or improper usage.

As the subject may be new to some present, it is necessary to revert to what may be well known to others; I therefore crave indulgence while referring to what led to the development of this design. It is, I believe, acknowledged by those who have studied the subject that distinct variations in hospital-planning have been principally brought about as knowledge has increased of the necessity for efficient ventilation, and of the means by which it can be secured. If that be granted, then it ought not to be surprising that with mechanical means at our disposal an attempt should have been made to design a hospital suited to be efficiently ventilated by such means, and that at the same time good engineering skill should be brought to bear, so that the mechanical appliances may be of the best, and thoroughly suited to the requirements of the building.

I have not the least desire, at the present time, to raise controversy on the subject of mechanical *versus* natural means for securing ventilation, for it must be evident to all that without mechanical means it would be impossible properly to ventilate such a block of building as this which we are considering. I enter no plea now for the adoption of mechanical means for securing ventilation. To my mind, and that of many others, judgment has already been given upon the principle, and it would now be as unreasonable to condemn the employment of mechanism for securing ventilation as it would be to assert that sailing vessels can compete with steamships for speed, carrying capacity, or punctuality, and would suffice for the commerce and navies of the world. Yet, although the principle has been conceded, there are many questions as to the best methods and appliances to be employed. It is over twelve years since Mr. William Key, of Glasgow, proved the possibility of securing efficient ventilation on the "Plenum" system, and as that is undoubtedly the most suitable for hospital purposes I am greatly indebted to him for devising the means by which it can be practically accomplished. Discrimination and increased knowledge are still wanting as to what constitutes efficient ventilation under varying circumstances; but, judging from the advance in favour accorded to the means and methods introduced by Mr. Key, "Plenum" ventilation has come to stay, and in my opinion it behoves us as architects to master its details, and apply them with judgment for the benefit of the public.

When the Committee decided to employ "Plenum" ventilation throughout the large General Hospital at Birmingham, ten years since, the opposition which faced me was, to say the least, disquieting, and it was somewhat unfortunate that the building was designed before it was determined it should be mechanically ventilated, for it entailed many constructional difficulties which had to be overcome. I have reason also for regretting that, contrary

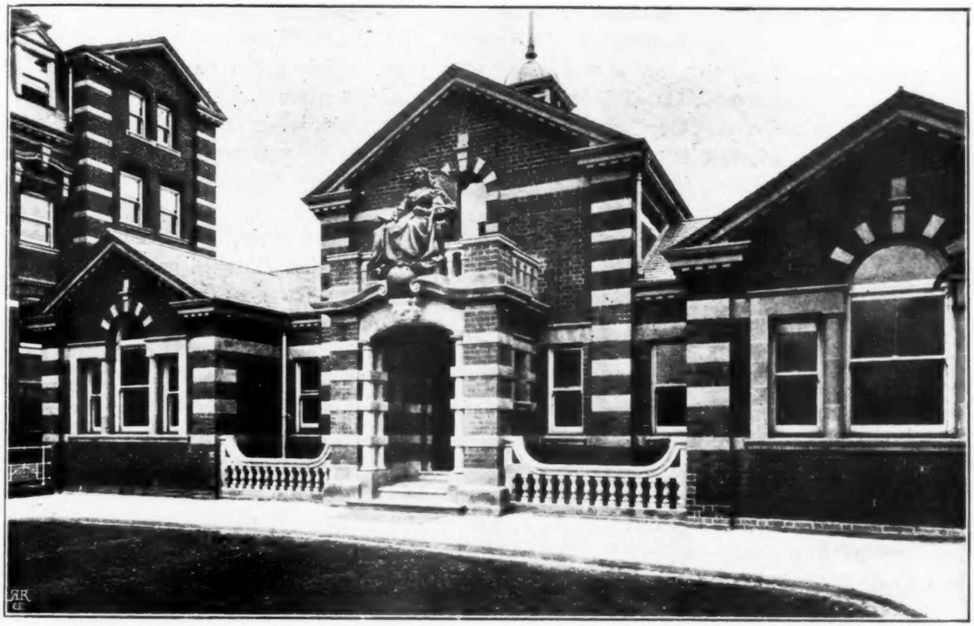


FIG. 2.—THE PRINCIPAL ENTRANCE, ADMINISTRATIVE DEPARTMENT.

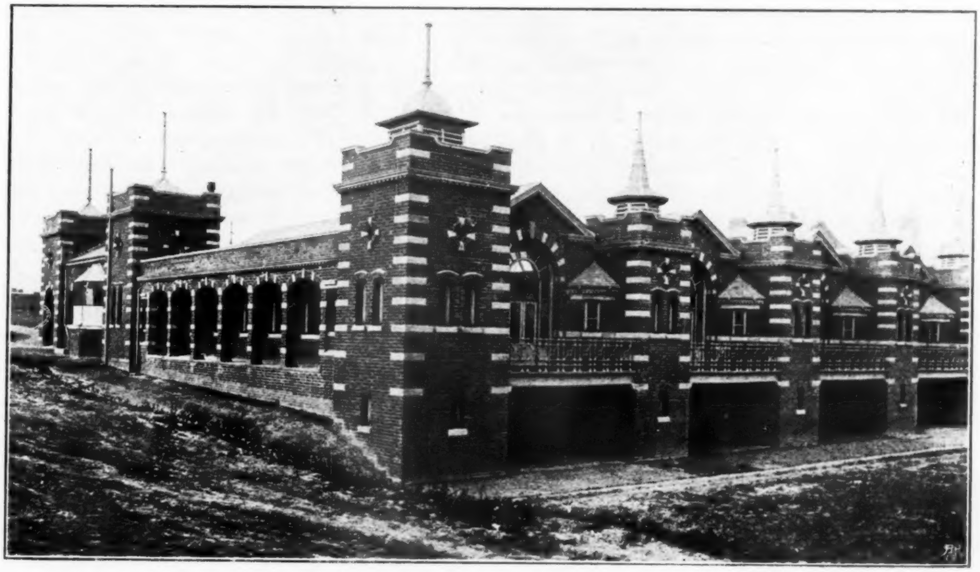


FIG. 3.—VIEW FROM THE SOUTH-WEST

to my opinion, the residential staff and nurses' quarters were included in the scheme; for although I believe efficient ventilation is secured throughout, the cost of upkeep is unduly increased by mechanically ventilating a large section of the buildings consisting of numerous small rooms, occupied only for a few hours at a time, which could have been reasonably ventilated by simpler methods, and by opening the windows when the rooms are unoccupied. The temperament of people in health varies so greatly that, when deprived of the right to open or close a window at will, it is next to impossible to persuade them their rooms are efficiently ventilated, and however good the system may be, some will unreasonably condemn it.

In the wards of a hospital, however, the conditions are entirely different. Occupied throughout both day and night by a number of patients in a low state of health, continuous change of air with an equable temperature and freedom from draughts, secured without noise or dirt, is an ideal state in which health and strength may be regained. The question consequently resolves itself into, How can hospital wards be designed and arranged so as economically and effectively to secure those desirable conditions? Such was the problem which for some time had occupied my mind when correspondence appeared in *The Builder* suggesting that, "in consequence of the proved success of 'Plenum' ventilation, combined with antiseptic treatment, it might be possible to dispense with the 'Pavilion' arrangement of wards," such change being principally advocated in the interests of more effective architectural treatment of the buildings. To this end were advocated double wards divided longitudinally by dwarf partitions. This suggestion appeared to me to be altogether wrong, so I wrote the following letter which appeared in *The Builder* of the 8th August 1896:

Sir,—Although the time may be at hand when it will be possible, by the employment of scientifically-applied means of ventilation and of the antiseptic treatment, to adopt an arrangement of plan differing from single-ward pavilions, the question demands closer examination than "F.R.C.S." and "Architect" appear to have devoted to it, for fear of a retrograde movement.

The point upon which they place so much stress—viz., architectural effect—is of slight importance to the welfare of patients and ease in administration, which in a hospital ought to receive first consideration, and other reasons given for reverting to double-ward pavilions are trivial. In fact, I venture to say that by far the majority of those who have had practical experience in hospital work will condemn the dwarf central division, because it obstructs a full view of the beds, and because it is not possible to so thoroughly light a wide ward; for it must be remembered that, although in a single ward a patient now and then may be inconvenienced by glare of light, that light is, in effect, the great health-giver to by far the majority. Ventilation, by whatever means secured, becomes more difficult in a large area, and a central division must retard free circulation of air; moreover, such enlarged spaces would demand greater height, which would further increase the difficulty of securing efficient ventilation, and add to cost as well as to labour in getting from one floor to another.

The real disadvantage of the pavilion plan, particularly in some of the large and recently-erected hospitals, is that of administration, in consequence of the great distances which have to be traversed by the staff; the direction, therefore, in which advance should be sought is concentration of wards, which becomes possible with an efficient system of ventilation and the employment of antiseptics.

Hospitals and infirmaries may be considered "health factories," and the arrangement of plan should, as in an ordinary manufactory, principally be considered with a view to perfection of work and its accomplishment with ease and despatch.

What I would suggest is that, instead of erecting detached pavilions of several stories, it might be better to spread out the wards on one story only, placed side by side and lighted by continuous lantern lights. Such an arrangement would secure greater comfort to the patients, simplify ventilation by mechanical means, and very considerably reduce corridor communication, as well as dispense with the inconvenience of staircases and lifts, thereby facilitating administration.

For the accommodation of the staff there would be no objection to buildings of several stories,

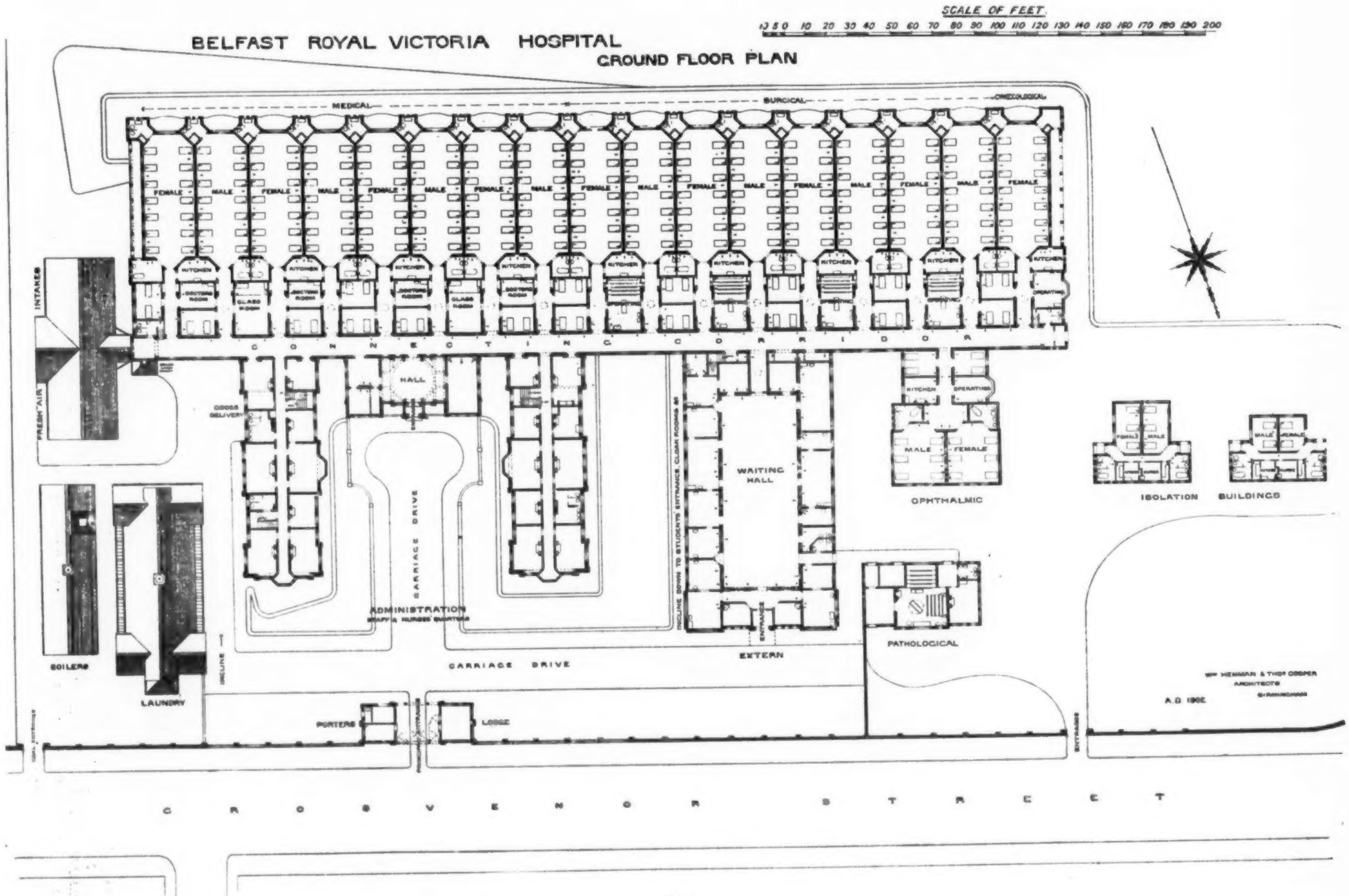

BELFAST ROYAL VICTORIA HOSPITAL
GROUND FLOOR PLAN
SCALE OF FEET
MEDICAL
SURGICAL
FEMALE
MALE
KITCHEN
CONNECTING CORRIDOR
HALL
WAITING HALL
ADMINISTRATION
CARRIAGE DRIVE
EXTERN
ENTRANCE
OPHTHALMIC
ISOLATION BUILDINGS
PATHOLOGICAL
LAUNDRY
BOILERS
INTAKES
FRESH AIR
PORTERS
LODGE
A.D. 1902
GROSVENOR STREET

FIG. 4.

but with all the patients compactly arranged on one floor level their wants could be easily supplied, and other difficulties of the pavilion plan would be overcome.

I am fully aware that only those who study what is possible with the plenum system of ventilation properly applied can realise the practicability of such an arrangement; yet by its employment I feel convinced that some such revolution in hospital planning will be accomplished, and do not doubt that in time it will be demanded, partly in consequence of the great cost of the pavilion plan, but more particularly in consequence of the excessive labour thereby involved.

WILLIAM HENMAN, F.R.I.B.A.

It never occurred to me, when that letter was published, that it would ever fall to my lot to design such a building for execution. Yet some three or four years later I was requested to meet the Committee of the Royal Victoria Hospital, Belfast, funds for a new building having been collected as a Jubilee Memorial to our late Queen, mainly through the untiring energy of Mrs. Pirrie, whose husband, the Right Hon. W. J. Pirrie, was at the time Lord Mayor of the city. When discussing the general arrangement of plan with the Committee, reference was made to the suggestions contained in the above letter, and I was questioned as to the practicability of constructing a hospital such as I had proposed. A majority of the Committee being favourably impressed with the assurances I was able to give, sketch plans were demanded.

On attempting to fit together, on entirely new lines, the intricate requirements of a complete hospital for 300 patients and a large staff, I began to realise the difficulties I had imposed upon myself. After several attempts and minor compromises in respect to some of the accommodation thought to be necessary, and with the able assistance of my partner, Mr. Thomas Cooper, the plan in time assumed the generally symmetrical arrangement in which it now appears an erected building; but ere it reached that stage, opposition was raised by some members of the Committee, and outside influence was brought to bear against the scheme. Of this we had no reason to complain, for we learnt that Belfast men can be just and considerate in opposition and are open to conviction. Some we know went to considerable trouble, visited other hospitals, and consulted supposed authorities to obtain evidence against the adoption of the plan. It was an anxious time when the Committee met to decide the question. The Chairman (Mr. Pirrie), the late Dr. Cummin, and others who advocated the scheme, after careful study of the proposals, stuck to their guns, but there was a strong opposition and some waverers; the matter hung for a time in the balance until Professor Byers, a member of the Council of the British Medical Association, and an hon. member of the medical staff, rose and spoke to this effect: "When first he heard that it was proposed to place all the wards side by side without intervening open spaces, to light them principally from above and to have no windows to open, it appeared to him so contrary to all his preconceived ideas on hospital design that he determined to oppose the carrying out of such a plan by every legitimate means, and, to enable him to do so effectually, he set about independently to study the subject in all its bearings; but, to his surprise, the more thoroughly he probed it the more and more convinced he became that Mr. Henman was right." He then went over the principal arguments for and those advanced against the scheme, and it was proposed that, subject to the general requirements of accommodation, "the architects be requested to develop the plan in such a manner as in their judgment would best meet the demands of the principle of a one-story hospital, with the wards compactly arranged side by side." *

* No record was kept as to what Prof. Byers said on that occasion, so I sent him a draft of what I have just read and asked for his personal experience of the working of the hospital, to which he kindly replied thus: "I remember quite well the incident, and may add that, after a trial of two months the new hospital has more than fulfilled my expectations. "The 'Plenum' system of ventilation and heating works admirably, and whether from the point of view of administration, ease and comfort of patients, or adaptability to clinical teaching, I know no hospital equal to it. We have had many visitors, and all regard the New Royal Victoria Hospital as unique of its kind."

Such forcible advocacy from a medical man of standing, until then absolutely unknown to us, took everyone by surprise, and the resolution was almost unanimously adopted. Thereupon several advocates of the scheme became enthusiastic with regard to it; ideas as to the accommodation to be provided enlarged, and we were led on to elaborate the architectural character, but again we experienced a check. Tenders for the erection of the buildings were received in the early spring of 1900—just when prices had run up abnormally, and little was thought of but the disasters of the South African war; the cost came out at a higher figure than was expected, and beyond the funds at disposal. No one had heart to appeal to the public for increased subscriptions, and no course seemed open but to bring down the accommodation to original requirements and to simplify the architectural

FIG. 5.—THE CONNECTING CORRIDOR.

treatment. This gave opportunity to a section of the Committee for reopening the question of the arrangement of plan, and, in addition to repeating objections previously raised, they urged it must be expensive; but fortunately the majority held to the principle of the scheme. In due course the design was modified, and on fresh tenders being procured the work fell to Messrs. McLaughlin and Harvey, contractors of Belfast, who have carried out the buildings in a very satisfactory manner, Mr. G. A. Flower acting as clerk of works.

Although one can but regret losing the chance of carrying out a large building of good architectural treatment, I am now inclined to believe that, in the interests of hospital development, things have turned out for the best: for not only would the additional cost have been put down to the particular arrangement of plan, but it is now realised that the annual cost of maintaining a larger establishment would have been beyond the means procurable. The buildings are not unsightly, though novel in character and simple in architectural design,

and when the grounds around are laid out and planted, time being allowed for trees and shrubs to grow, their appearance will doubtless be improved.

The cost of the buildings, including all engineering requirements and a complete steam laundry, is only a trifle over £300 per patient's bed; which is clear proof that the arrangement of plan is capable of being carried out at an economical figure.

The site is an excellent one, being a portion of the grounds of the old Asylum: it was granted by the City authorities with the sanction and, I may say, the approval of the ratepayers. It is six acres in extent, to which another six acres is to be added on the completion of a new asylum which is being erected elsewhere. The hospital stands comparatively high, has a pleasant outlook in every direction, and is readily accessible from most of the large manufactories and works, and from the poorer parts of the city, whence the majority of the patients will come. From west to east there is a fall in the level of the ground of over twenty feet, of which advantage has been taken; by keeping the main floor level well above the ground adequate height is secured for the principal fresh air-duct, which runs under the main corridor, and for the branch ducts conveying fresh air to the several wards and accessory rooms. There is also a pipe-duct running parallel with the principal air-duct—a necessary provision, so that heat from the steam and hot-water pipes may not penetrate the buildings during the summer months, and that convenient access may be obtained to all piping.

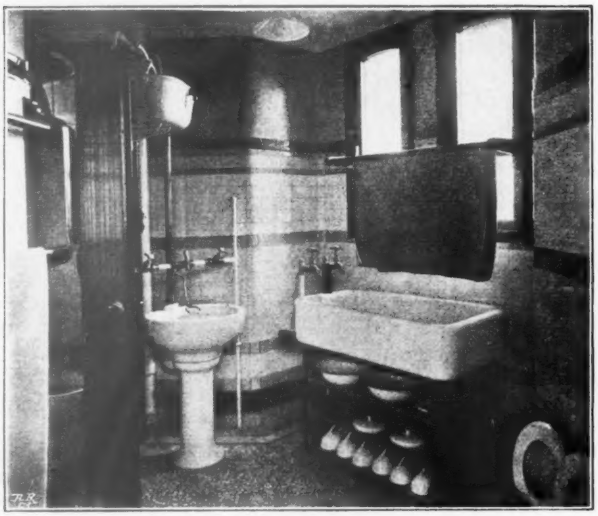


FIG. 6.—A SANITARY TURRET.

The entrance to the site is on the north side from Grosvenor Road, which at that point was several feet above the average ground level; consequently by making up an entrance roadway to the street level the buildings are approached on the flat and the basements of the east and west administrative wings are retained clear of the ground. These are the only portions of the buildings which are of more than one story, and being on the north side there is no overshadowing of the patients' departments.

The official entrance is centrally placed between the east and west wings. Through an open porch, surmounted by a bronze statue of Queen Victoria executed by J. Wenlock Rollins, sculptor, of Chelsea, is a domed entrance-hall lined with Irish marbles and alabaster. On the right is the Board room, on the left the Superintendent's offices and waiting-room. Opening directly from the hall opposite the porch entrance runs the main corridor from east to west, some 450 feet long and 9 feet wide. Branching southward are seventeen short corridors, giving access to as many wards, each for fourteen beds, with their accessory rooms, all practically under one roof. The eight wards to the east are for medical cases; then come eight wards for surgical cases, and one for gynæcological cases. To the north are two wards for ophthalmic cases.

The arrangement of the wards is on the "unit" principle—*i.e.* each honorary physician and each honorary surgeon has control of a male and a female ward, with their accessory rooms. To each group of four medical wards there is a class room, approachable without the necessity for passing into the main corridor, and two clinical rooms. To each pair of surgical wards there is an operating room, and, in addition, separate operating rooms for gynæcological and ophthalmic cases. A ward kitchen serves for each pair of wards (except the gynæcological, which department is self-contained). Small wards of two beds each are provided in connection with each large ward; linen cupboards in the branch corridors, also store rooms for patients' own clothing, and conveniences for nurses as well as cleaners' rooms, with slop sinks at the ends of the main corridor.

FIG. 7.—THE CENTRAL HALL OF "EXTERN" DEPARTMENT.

Sanitary conveniences are in a turret at the south end of each ward; bath rooms and lavatories at the north end. I may here direct attention to the fact that intercepting lobbies between wards and conveniences are dispensed with. Open windows with "Plenum" ventilation are objectionable, and without open windows intercepting lobbies are an anomaly. By simple adjustment it is possible to ensure that air from sanitary turrets shall not enter the wards, air pressure in their direction being maintained from the wards outwards. This is a matter of importance, because on examination I have frequently found that, notwithstanding intercepting lobbies, when natural means of ventilation are relied on, air is drawn or forced into the wards from the sanitary turrets. This, as I have said, is obviated when "Plenum" ventilation is employed, in addition to which the service of the wards is facilitated, for there is no real necessity for doors, which at busy times are frequently fixed open, and then the intercepting lobby is useless. For the sake of privacy, however, doors are supplied, hung folding

with light spring hinges, through which it is easy to push one's way, even with hands fully occupied, for it often happens that nurses and ward maids have to pass into and out of the sanitary turrets with hands full of breakable articles. Similar doors hung on light spring hinges are provided to all entrances to wards, bath rooms, class and operating rooms, to facilitate the passage of ambulance and other trollies. To the ward kitchens no doors are provided, for with "Plenum" ventilation an equable temperature and freedom from draught are secured; consequently inner doors are required only for the sake of privacy or where difference of temperature is desired to be maintained, such as between the main and branch corridors.

The "Extern," or out-patients' department, is situate between the administrative buildings and the ophthalmic wards, with a public entrance at the north end, right and left

FIG. 8.—ONE OF THE WARDS.

of which are rooms for a charge nurse and the registrar, receiving room for casualty cases, and room for minor operations. Centrally is a large waiting hall, around which are medical, surgical, and specialists' consulting rooms, with several examination rooms. The dispensary is placed near the medical wards, for at this hospital medicines are not dispensed to out-patients.

Students, both male and female, are provided for in the basement of the Extern building, with a stairway up to the main corridor. The Extern waiting hall also connects with the main corridor, as all patients are admitted through the "Extern"; an arrangement which in practice is found to avoid delays and inconvenience, which often happen when there are two or more entrances, and patients go to the wrong one.

Two small detached buildings at the west end of the site are for isolation purposes: they receive fresh air by a continuation of the main duct underground, and, although at least 600 feet away from the fans, are amply supplied with fresh air.

BELFAST ROYAL VICTORIA HOSPITAL

PLAN AND SECTIONS THROUGH AN OPERATING ROOM.

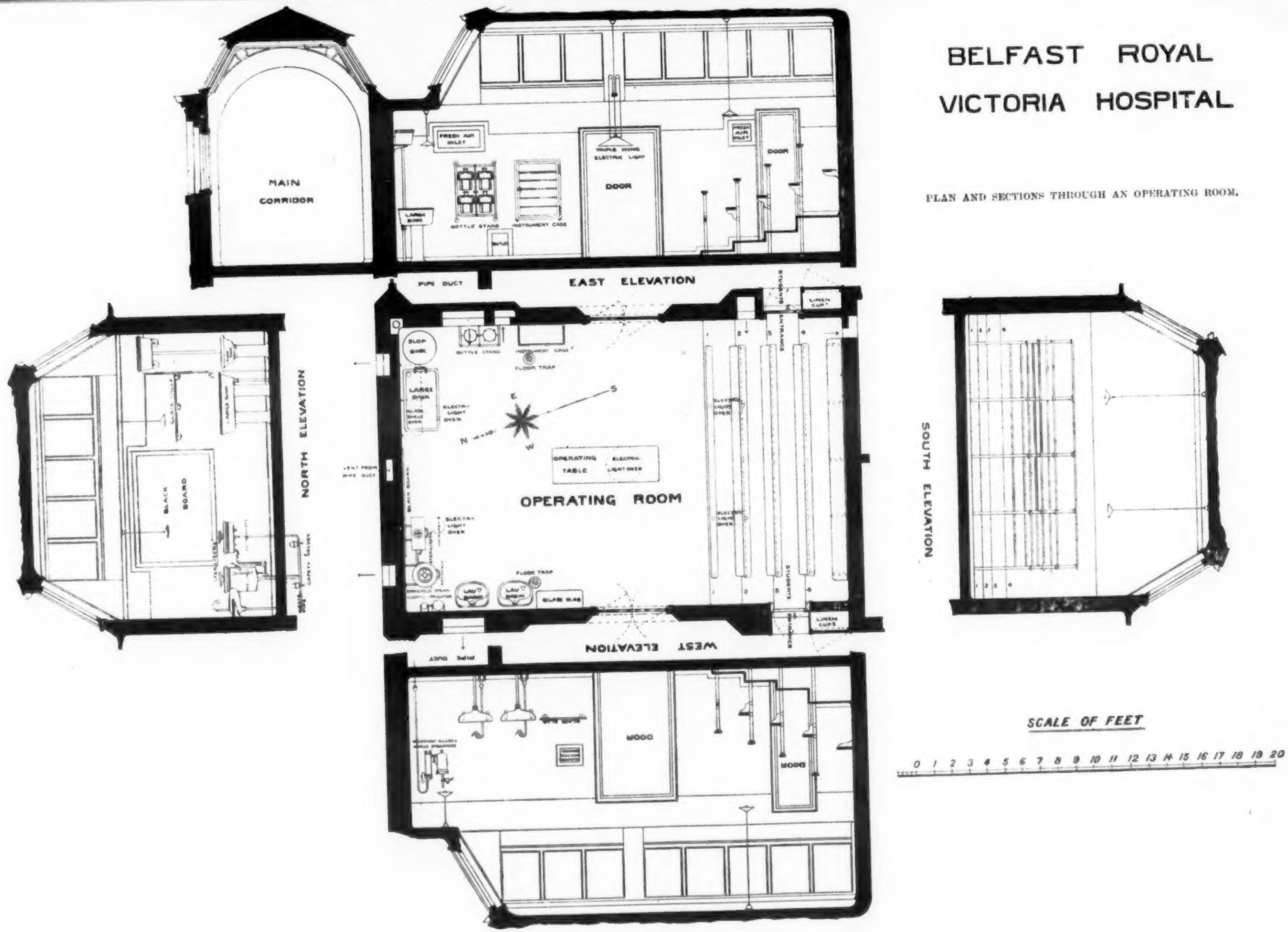


FIG. 9.

Sections through a portion of the ward block give a general idea of the method of lighting, and of the construction adopted. Tie-beams, which would form objectionable lodgment for dust, are dispensed with, support being obtained by means of rolled steel joisting within the roof space, arranged to the form required, strengthened by angle-plates, and riveted together continuously from end to end, resting on the walls dividing the wards, the extreme ends being held down by bolts built into the piers of the outer arcadings.

Only the two outer wards have side windows, not really necessary, but inserted because it was possible to provide them. All the principal wards have large south windows, with casement doors opening on to balconies, and lantern or clerestory lights from end to end on both sides. These are not skylights, as generally understood, but are more properly defined as clerestory windows, slightly sloping, and glazed with half-inch plate glass. All accessory rooms are similarly lighted. So are the main corridor, the extern waiting hall, and the laundry. The result is most perfect lighting to every portion of the building. We were led to adopt an angle of 60 degrees with the horizon for these clerestory windows, in consequence of the researches of M. Trelat, a well known authority on hygiene, his opinion being that, not only is an abundance of light necessary for maintaining a healthy state within doors, but the best light is that which is admitted at an angle of 30 degrees with the horizon. Consequently, it is that good light which is admitted at right angles to the glass, and passes through without being refracted. Surgeons who have seen and utilised the operating rooms inform us that nothing could be better for their purpose, because the light is ample, well diffused, and practically free from shadowing. A proof of this is afforded by a complaint of the photographer, when he first essayed to take views of the interior, that they came out flat and devoid of proper shadowing; but by darkening the windows on one side better photographic results were obtained.

An advantage of "Plenum" ventilation, not always appreciated, is that the cubical contents of buildings may be very considerably reduced. With ordinary haphazard means for securing ventilation, there is a continual demand for more and more space in hospital wards, but given sufficient floor area for nursing and teaching purposes, the height of wards need be no more than appearance demands, and when lighted as they are in this instance the cubical contents are much reduced, being not more than two-thirds of what is ordinarily required, thereby effecting considerable saving in cost.

The arrangement of lantern lights and flat asphalted roofs also facilitates window cleaning, by which a considerable saving is effected, not only in actual outlay, but in damage to the buildings and surroundings by the constant moving about of lofty ladders.

The administrative buildings need little detailed description. In the basement of the west wing is the kitchen department, with serving room on ground floor, about central to the main corridor, to facilitate the distribution of meals. Store rooms occupy the basement of the central block and east wing, and on the upper floors is sleeping accommodation for the superintendent, the matron, 8 resident medical and surgical officers, 76 nurses, and 32 male and female servants, sitting and meal rooms being principally on the ground floor. The corridors are all well lighted, warmed, and ventilated. Each room is provided with a flue carried above the ridge of the roofs, and all windows are constructed to open. Gas fires are provided in the sitting rooms to obviate the necessity for conveying coal about the building.

Having, I hope, given you a general idea of the arrangement and appearance of the buildings, let us turn to the fittings, for I hold that no detail, however insignificant, should be ignored by the hospital architect; he must meet all reasonable requirements of the medical, surgical, nursing, and domestic staff. Unfortunately, one and all of them may differ on important points; but if the architect has had varied practical experience, his knowledge of

constructional requirements, sanitary appliances, and plumbing work should enable him to reconcile divergent opinions, decide what is really necessary, discriminate between the truly useful and merely fanciful fittings at times demanded or put forward by interested manufacturers, and by careful design, judicious selection, and securing good workmanship, the annual expenditure on repairs and replacements may be confined within reasonable limits, and the necessary daily work in a hospital may be performed without excessive labour or irritation.

Our endeavours in this direction were encouraged by the Committee, and the hospital owes a deep debt of gratitude to the indefatigable labours of Mr. and Mrs. Pirrie; for not only have they, in their frequent travels abroad and in America, sought out the latest and best furniture and fittings which could be procured, but Mr. Pirrie's intimate knowledge of shipbuilding and fitting has been freely brought to bear on what may be termed the domestic fittings in the hospital, so that a suitable place has been found for every requisite, and everything is suited to its place.

The increasing difficulty experienced in securing adequate funds for the upkeep of hospitals is a serious drawback to many institutions, and, although by no means an advocate for the cheap and nasty, I am convinced that greater economy could be exercised in hospital design and equipment in a way to reduce annual expenditure; and if our endeavours at Belfast tend to that end, one object we have had in view will have been attained. Work carried on in hospitals is of vital importance, often severely taxing the skill and energies of those who labour therein; consequently, the work of the architect should aim at securing the reas nable comfort and convenience of the medical, surgical, nursing, and serving staffs, as well as of the patients.

In each sanitary turret is a w.c. with lift-up teak seat having the back and front cut away to avoid soiling, the flushing cistern being of glazed earthenware; a slop sink with similar flush cistern, and special contrivance for bed-pan washing, supplied with hot and cold water; a large flat sink for washing utensils and macintoshes, above which are teak rails where the latter can be hung to drain, other rails being provided for them to hang on when dry. Under this sink is a stand, also of teak, with draw-out trays for utensils, and fixed to the wall are racks for bed-pans.

The bath rooms are supplied with a slipper-bath of white earthenware, glazed inside and out. The waste is on the screw-down valve principle, of large bore to discharge quickly into a floor-trap, and the overflow is simply an opening at the side, which also discharges into the floor-trap. Hot and cold water are of course laid on, and there is a single lavatory bracketed from the wall.

The fixed fittings in each operating room comprise two lavatory basins, with treadle taps and lever arrangement, worked by the elbow, for securing either a jet or spray of water; a large sink and slop-hopper, with flushing rim and cistern; a "Berkefeld" aseptic irrigator with steam supply, so that sterilised water can be at once obtained to any required temperature. The sterilisers for dressings and for instruments have been specially designed and made for this institution: the general form was suggested by Professor Kirk, who devoted a great amount of attention to securing a perfectly effective and safe arrangement. After many inquiries nothing could be procured at a reasonable price which would answer to requirements, so experiments were instituted. These were undertaken by Messrs. Millin, of Belfast, who devised an inner coil instead of a double jacket as usually employed, steam being the heating power. Other improvements are a simple wheel action for opening and closing the lids; an indicating valve by which all danger resulting from having separate valves is avoided; and a large dead-weight safety valve to each apparatus. Condense-water

and waste steam are taken into a cast-iron drain placed in the pipe-duct below, so as to avoid nuisance therefrom in the operating rooms.

A stand for aseptic fluid bottles and the instrument case are bracketed from the walls.

Electric switch connections are provided for surgical use, and triple-balanced electric lights are suspended over the operating table—single lights elsewhere. For teaching purposes there is a fixed blackboard and raised seating for students.

In the post-mortem room, special sinks with various valves and wastes, lavatory basins and slop-hopper, are provided, also raised seating for students.

The pathological and microscope rooms have special fittings for the class of work which will therein be carried on.

Throughout the administrative buildings the same care has been bestowed on all the sanitary appliances, the whole of which have been carried out from our designs by Messrs. Morrison & Ingram in the most satisfactory manner, and fixed by Mr. John Dowling, plumber, of Belfast.

As my friend Mr. Henry Lea, who so ably seconded our endeavours by designing all the engineering details in accordance with requirements, has kindly undertaken to explain them, I leave to him to describe the contrivances by which this hospital is lighted, ventilated, warmed, and provided with a continuous supply of hot water.

In conclusion, however, let me say that I have always deprecated the use of the term "model" to any class of building: each should be designed to meet special requirements. It would be presumptuous to suppose we have designed a perfect hospital, one which is to be held up as a model for the future; nevertheless, an entirely new departure has been made, and judging from the favourable opinion already accorded to it by those who have to work therein, or have thought it worthy of careful inspection, we believe it will repay all who are interested in hospital design to study it closely, and should others see fit to follow in our footsteps and, maybe, to improve upon our endeavours, we should consider it a flattering compliment. I must, however, add a word of caution. Good and useful as I thoroughly believe "Plenum" ventilation to be, particularly for hospital purposes, it is essential it should be applied with full knowledge and by those competent to deal effectively with it; distrust every engineer who will give a scheme for ventilating any building indiscriminately on the "Plenum" or "Extraction" system, or by what are termed natural means; but try to realise that every building should be designed for the particular method of ventilation intended to be employed, and that the means for procuring ventilation must be specially designed on scientific principles to meet the actual requirements of the building.

II. THE ENGINEERING WORK. By HENRY LEA, M.I.C.E., M.I.M.E., M.I.E.E.

I. VENTILATION.

MR. HENMAN has truly said that the adoption of the Plenum system of ventilation enables the architect to design a hospital on lines entirely different from those which are commonly accepted; and, on the other hand, I would say that the design which Mr. Henman has originated does in its turn facilitate to an extraordinary degree a simple arrangement of air-ducts of ample proportions. I do not think that the importance of this point has been sufficiently realised; and to emphasise this view I would mention two large buildings now ventilated by mechanical means, each requiring about 13 million cubic feet of fresh air to be driven through them per hour. In each of these buildings electricity, taken

from the public supply mains, is the motive power used for driving the fans. In one building, owing to the liberality with which the air-ducts are proportioned, the total amount of power required to drive the fans is 19 e.h.p.; in the other building, owing to the air-ducts being restricted and very crooked, the total power required to drive the fans is 53 e.h.p. Now, in hospitals where the ventilating operations have to be carried on day and night all the year round, the cost of driving the ventilating fans becomes a matter of serious importance. If we convert the above-mentioned amounts of power into money-value, we find that, taking the cost of electricity at $1\frac{1}{2}d.$ per unit, the power required in one case is costing £766 per annum, and in the other £2,164 per annum. If it be contended that air-ducts of ample proportions and of simple design are too costly in capital expenditure, I would point out that, capitalising the difference, £1,388, between £2,164 per annum and £776 per annum at 5 per cent. interest, we obtain a sum of £27,760. If the whole of this amount were to be expended upon larger and more direct air-ducts, the interest on the extra outlay would balance the saving in electricity, and no particular advantage be obtained. But it would be impossible to devote to the improvement of the air-ducts anything like so large a sum as £27,760; and assuming for a moment that the sum of £3,760 were devoted to the air-ducts, there would still remain a clear saving equivalent to £24,000 capital, or at the rate of £1,200 per annum, in the cost of driving the fans.

Mr. Henman's drawings show the general arrangement of the air-ducts, and it will be seen that as regards simplicity they leave nothing further to be desired. As regards their size, the main air-duct at the end nearest to the fan chambers has a height of 20 feet and a width of 9 feet. The full width is preserved to the far end of the wards block, a distance of 443 feet; but the bottom slopes upwards, so that the height is diminished to 6 feet at the far end. The total cubical capacity of the hospital buildings ventilated on the Plenum system is 703,000 cubic feet. With seven changes of atmosphere per hour in the winter the velocity of the air entering the main duct is 7·06 feet per second, and with ten changes per hour in the summer the velocity is 10·85 feet per second. The proportions of the branch ducts and of the vertical air-flues are based upon similar liberal lines, as are also the air-ways through the fan chambers and the water screens. Herein lies the secret of the reduction of power for working the system. In the case of the Royal Victoria Hospital the expenditure of power per million cubic feet of air per hour is very considerably lower than in any other instance that has come under my notice.

The particulars of the power required will appear later on.

Another point in relation to economical working is that the fans are driven by a steam-engine, the exhaust steam from which is utilised for heating the water for the baths and lavatories throughout the building. The quantity of exhaust steam issuing from the engines is hardly sufficient for the purpose, and has to be supplemented by a small quantity of live steam. The economical effect may therefore be regarded thus: If electricity from the public supply mains had been used for driving the fans, there would still have been required steam for heating the hot-water supply. As the steam for this purpose is now first of all passed through the steam-engines on its way to the calorifiers, it may fairly be said that the saving effected is the cost of the electricity which would have been used if the fans had been driven by electric motors instead of by steam. Taking the mean power required throughout the year at $5\frac{1}{4}$ h.p. and the cost of electricity at $1\frac{1}{2}d.$ per unit, there is a saving under this head of £214 per annum.

Having thus alluded generally to some of the main engineering features of the hospital, I shall now proceed more into detail.

There are two Lancashire boilers, each 7 feet 6 inches diameter by 28 feet long, and there

is room for a third boiler to be put down, if necessary, upon some future occasion, between the boiler-house and the laundry. The steam is led from these boilers through the steam-pipes to the various points where steam is required. The boiler seatings and the steam-pipes at the back of the boilers are arranged so that superheaters may be added. The author fully realises that these appliances would be of very great value, but at the time when the specifications were drawn it was impressed upon him that almost the most important thing of all was to keep the cost of the work down as low as possible, and the superheaters have therefore been omitted for the present. It is hoped, however, that it will not be long before so valuable an accessory is provided. At the back of the boilers are the stack; the condense-water tank, into which all the steam-traps in the building discharge their condense-water; and the pump-house, containing feed-pumps in duplicate for pumping the hot and pure condense-water back to the boilers, together with so much fresh water as may be necessary for making up for steam used for cooking and for some purposes in the laundry, where it is not practicable to recover the condense-water. To the right of the boiler-house block are the north heating chamber, the north fan, the south heating chamber, the south fan, the north and south heating-coils and the north and south washing-screens, the engine-house, and the air-ducts leading from the two fans to the main air-duct.

Fig. 10 shows in sectional plan the arrangement of the engines and fans; fig. 11 shows a vertical section taken on the line E F. There are two steam-engines, each of the horizontal type, having cylinders 9 inches diameter by 16 inches stroke. One of them, marked N E, lies to the north; the one marked S E lies to the south. Either or both of these two engines can be made to drive the pulley P by means of the clutches S C, N C. The belt B drives the fan-pulley F P and the clutch-shaft C S. By means of the fan-clutches F C either or both fans can be connected to the clutch-shaft C S. The north fan is marked N F, and the south fan is marked S F. Each fan is 110 inches diameter. By this arrangement the north engine can be set to drive either the north fan or the south fan, and the south engine can also be set to drive either fan, or either engine can drive both fans, or both engines can drive either or both fans. One engine and one fan are amply sufficient for changing the air throughout the hospital seven times an hour, with the expenditure of $5\frac{1}{4}$ i.h.p., or at the rate of about 1·07 i.h.p. per million cubic feet of air.

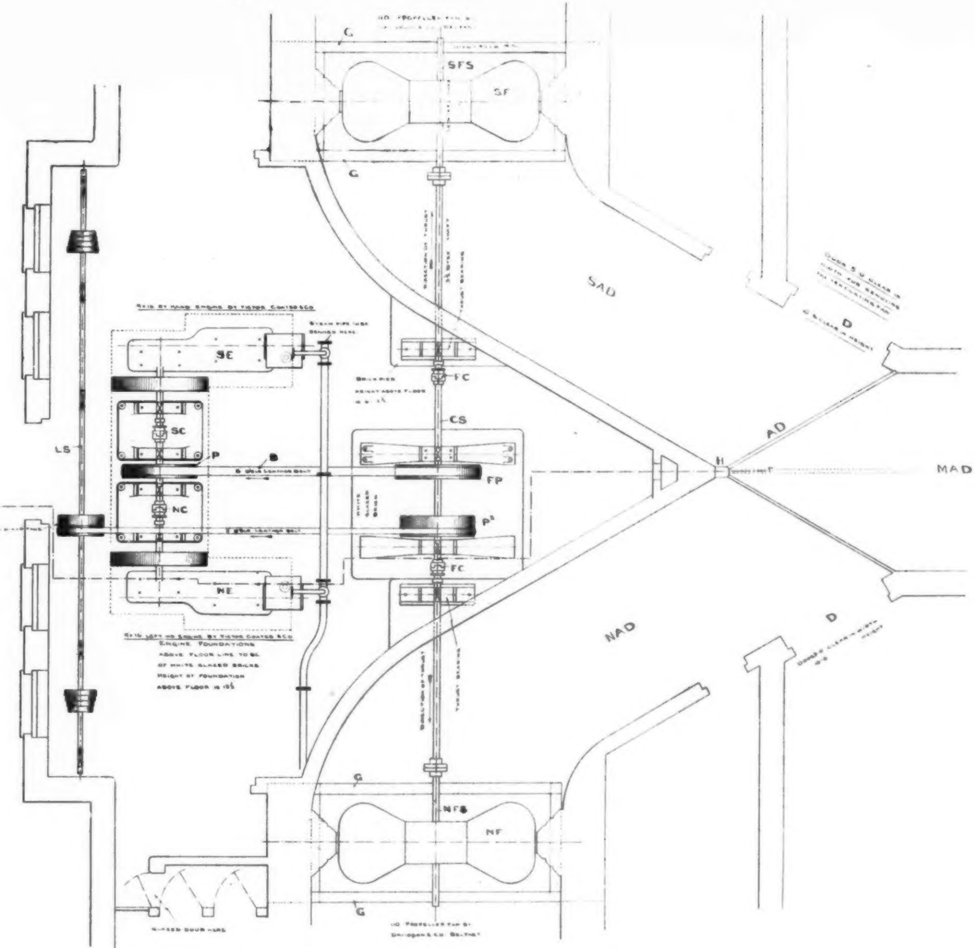
In summer-time, should ten changes of air per hour be required, both fans are set to work, with an expenditure of $10\frac{1}{4}$ i.h.p., or 1·45 h.p. per million. These figures are, as I have already said, the lowest which have yet come before my notice; and, as previously stated, this power is supplied at practically no additional cost to what would necessarily be incurred to secure a continuous hot-water supply.

The north fan-shaft N F S and the south fan-shaft S F S revolve in bearings which are bolted to the girders G. These girders are movable, so that should either of the fans ever require to be taken out the removal can be easily accomplished, the doorways D D being made sufficiently large to allow of the fans being taken through them. [See fig. 12.]

The north air-duct N A D and the south air-duct S A D converge to the main air-duct M A D. The air-door A D is hinged at H, and can be swung into either of the positions shown, so as to shut off the fan which is not working and allow of a clear passage for the air from the fan which is working. When both fans are working the air-door is placed in the position shown by the dotted lines. The pulley P 2 fixed on the clutch-shaft C S drives a line-shaft, marked L S, and from which is driven the circulating pump for the hot-water supply to be described later on. Fig. 12 shows one of the fans and one of the removable girders.

The external air on its way to the fan enters the heating chamber through openings in the outer wall. The entering air first encounters a series of vertical pipes, kept heated by

FIG. 10.



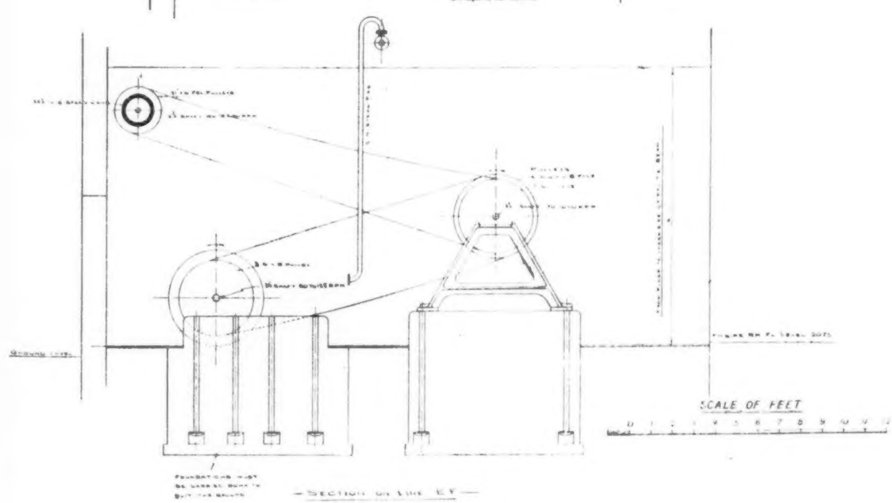


FIG. 11.

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steam. These pipes rise from hollow base-boxes, which are supplied with steam through suitable pipes. Each base-box has a longitudinal division cast in it, so that the steam which enters one side of the box is compelled to rise up one vertical leg of the outer coils and to descend in the other leg before it arrives at the outlet side of the base-box. The condense-water is drawn off through drain-pipes and steam-traps connected to both sides of each base-box. The air, slightly warmed by the outer coils, next passes through the cleansing screens. These consist of timber framing, the vertical portions of which are strengthened by being bolted to tee-irons. The horizontal portions are removable, and each panel comprises two strong wooden rollers, one at the top and the other at the bottom of the panel. Cocoa-nut fibre in the form of a yarn is wound from one roller to the other, over and under, and the fibres are stitched together close to each roller to prevent them from moving. The two ends of the upper roller rest on two chocks on two of the uprights, and the two ends of the lower rollers are then sprung underneath two similar chocks on the same uprights, so that the fibre of the screen thus formed is held in tension. In former installations of this kind the screens consisted of continuous yarns extending from the top of the screen to the bottom; but it was found that in course of time the upper portions of the screens became rotten and gave way, when the whole of the vertical length fell to the ground, and had to be renewed long before the lower portions had become unusable. By dividing the screens up into panels, and by making them in the manner already described, it is quite easy for the attendants to make up a few from time to time and keep them in stock, and the operation of taking out an old panel and putting in a new one is the work of a few minutes only.

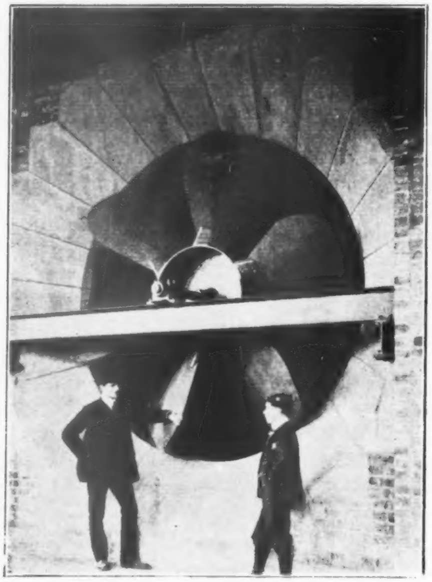

FIG. 12.

The cleansing screens are kept continuously wet by means of horizontal perforated sprinkler-pipes. These pipes are fixed outside the screens, near the tops of them, and about 12 inches away from them in a horizontal direction. They are supplied with water from a series of automatic flushing tanks, similar to those commonly used in lavatories, and each is set to discharge the requisite quantity of water about once every ten minutes. The water issuing from the perforations in the sprinkler-pipes strikes the tops of the screens and runs down the yarns to the bottom, thus keeping them thoroughly wet. After passing through the cleansing screens the air encounters the inner steam-coils, which are constructed in the same manner as the outer ones, and differ from them only in the number employed and in the fact that the steam passes from one base-box to another, so that the vertical legs are all heated in series by the same current of steam. This arrangement was devised in order to get rid of the very large number of regulating steam-valves which had been employed in previous installations, in some of which the valves may be counted by dozens, whereas in the author's arrangement there are only two regulating valves for each heating chamber—namely, one for the outer coils and one for the inner coils. These valves are placed in the engine-room, and by their use the attendant can adjust the temperature of the air with the greatest facility, being guided by the indications of a large scale thermometer, the bulb of

which projects into the fan-chamber, while the scale is visible in the engine-room. The object of the outer coils is to prevent the cleansing screens from freezing in very cold weather, the inner coils being used for raising the air to the required temperature after it has been cleansed by passing through the washing screens. The base-boxes of the inner coils rest upon strong wooden framing, the top of which is covered with 3-inch planks. The vertical spaces are closed by means of wooden louvre doors, which can be opened to allow cold air to pass direct underneath the inner coils on the way to the fan-chamber, should it be necessary to make a sudden reduction in the temperature of the air being supplied to the hospital. The occasions, however, on which this requires to be done occur very seldom. The condense-water drain-pipes from the base-box of the inner coils deliver into one condense-water-pipe main, which is led to a large cast-iron tank in a basement chamber near the boilers, which chamber also contains the duplicate boiler feed-pumps by which the condense-water is pumped back into the boilers hot and pure.

The surplus water from the cleansing screens falls upon the floor of the screen-chamber, which is laid to fall, as shown in the front and side elevations of the coils, and the foul water runs away to the main drain, special provision being made to prevent the possibility of drain-air being drawn into the air-chamber.

The function of the outer and inner steam-coils in the heating chambers just described is to raise the whole of the fresh air which enters the hospital to a temperature of about 58° F., which is a suitable temperature for the entrance-hall and the corridors. For the wards the temperature has to be raised to about 62° F., and occasionally for the operating-rooms to about 70° F. Supplementary steam-coils in the branch air-ducts are provided for this purpose. A winter steam-main, conveying steam from the boilers, runs along the whole length of the main air-duct. This pipe is not covered with non-conducting composition, because it is never used excepting when the temperature of the air requires to be raised in the main air-duct; and by leaving this pipe bare the heat from it contributes to the warmth in the main air-duct, to the extent, approximately, of compensating for the loss of temperature in passing along the air-duct. There is another steam-pipe, which is in constant use all the year round. This pipe runs along the pipe-duct, and is clothed with non-conducting covering. Underneath it runs the condense-water drain-pipe for returning the condense-water from the supplementary coils, to be described, back to the condense-water tank. The supplementary coils consist of vertical pipes connected to a base-box, as already described for the main coils. All the air that enters the branch duct has to pass across this supplementary coil. A branch steam-pipe conveys steam from the main pipe to the supplementary coil, and also feeds a ¾-inch wrought-iron steam-pipe, running the whole length of the branch air-duct, and returning at a slightly lower level. The condense-water from this pipe is conveyed to the condense drain-pipe, which runs along the whole length of the pipe-duct, and conveys the condense-water to the condense-water cistern already described. Other supplementary coils still further raise the temperature of the air going into the operating-rooms, and are under the control of those members of the staff who are using the rooms, the handles of the regulating valves being extended upwards so as to be adjustable from the operating-rooms. It was necessary to have a separate regulation for each branch air-duct, and therefore it was impracticable to effect this regulation from a central position such as the engine-house. As the main air-duct is 20 feet high where the air enters it, and as the winter steam-main runs very near the ceiling of the duct, a special form of regulating valve was designed by the author for the purpose. From the two ends of each valve lever depends a light chain hanging down in a loop to within easy reach from the floor of the main air-duct. A cast-iron quadrant, painted black with white figures upon it, is clipped to the steam-pipe, and when the end of the valve-lever, also painted white, nearest to this quadrant points to any number on the quadrant,

that number shows how many of the small holes in the valve-seat are uncovered to allow steam to pass. The admission of steam is therefore exactly proportioned to the position of the lever, and the quadrants themselves, being so large, are easily read from the floor of the main air-duct when the latter is moderately illuminated by means of the electric lamps provided for the purpose, or by means of the light from a hand-lantern directed on to the quadrant.

II. HOT-WATER SUPPLY.

A line shaft drives a rotary pump, which is used for accelerating the circulation of hot water throughout the entire hospital. It is introduced between the return-pipe in the engine room and the flow-pipe. Soon after leaving the pump the water passes through two calorifiers, of which the lower one heats the water by means of the exhaust steam from the steam-engines, and the upper one adds whatever supplementary heat is required by means of live steam direct from the boiler. The live steam calorifier has an automatic arrangement whereby the temperature of the water controls the admission of steam. The maximum temperature proposed to be allowed is about 160° F. This question of maximum temperature is a very important one, because upon it depends the durability of the hot-water taps throughout the building. Taps which work very satisfactorily at 160° are found to give an excessive amount of trouble if the temperature of the water is allowed to attain 200° and 212° F. There are two thermometers in the engine-room, namely, one on the flow-pipe and one on the return-pipe, so that the engine-room attendant can see at any time what the temperature of the circulating water is; and, there being no other means of heating the water besides the two calorifiers in the engine-room, the whole system is under easy central control.

The supply of cold water is brought from the cold-water cistern in the roof of the east wing, and is connected to the return-pipe, so that the cold water, after passing through the rotary pump, enters and is heated by the two steam calorifiers before it passes to the various portions of the building. There are stop-valves on the various pipes for the purpose of enabling the pump and the calorifiers to be attended to without emptying the circulation mains, and a provision is also made whereby either of the calorifiers may be removed in a comparatively short space of time, and its place taken by a plain pipe. During the time that either calorifier is absent the water continues to be heated by the remaining calorifier. A spare pump is also provided which in a comparatively short time can be put into the place of the acting pump, in the event of repairs being necessary. This arrangement was made in order to save the expense of a duplicate plant, and the complication of valves and pipes which would have been necessary in connection therewith.

The general arrangement of the hot-water circulation includes two hot-water cylinders, each containing 900 gallons of water. To the system of circulation are connected eight subsidiary circulations under the wards block, for the purpose of supplying the baths and lavatories in that block. Other subsidiary circulations are also provided for the ophthalmic block, the extern, and the administrative block.

At every necessary point is provided a tee-piece, containing an American pattern scoop for intercepting a portion of the water flowing through the main and directing it into the subsidiary branch. These scoops, taken in conjunction with the forced circulation produced by the rotary pump, are most important adjuncts, as they make quite sure that a rapid circulation of hot water shall pass through all branch pipes, even when the latter are laid on the same level as the main pipes. From each of these tees, which in the contract were called plumbers' tees, a service pipe is led to a bath or lavatory, as the case may be. The general principle of the whole arrangement is that there shall be a circulation of hot water immediately underneath every point at which hot water is required in a room above, so that when a hot-water tap is opened the water issues hot almost instantly, without waiting for a discharge

of water from a long pipe which has cooled down since it was last used. This arrangement is greatly facilitated by having a lofty basement under the hospital buildings, which, as you have been informed, are only of one story. Looped pipes are used for the purpose of allowing for the expansion and contraction of the mains, the mains themselves being firmly anchored to the walls of the building close to each loop, so that the expansion and contraction take place between each two points of anchorage, the extent of the movement being thus determined so as not to affect injuriously any of the branch pipes. All the hot-water mains and the branch

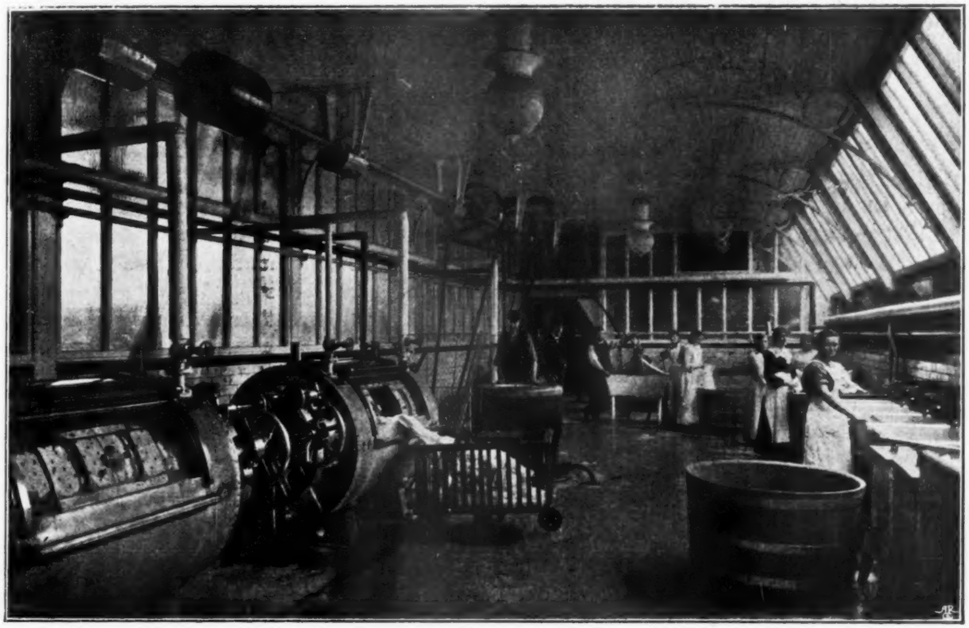

FIG. 13.—THE WASHHOUSE.

circulations are covered with non-conducting composition. The effect of the rotary pump is such that the hot water is caused to circulate through the whole system about once every fifteen minutes, which ensures that the temperature throughout shall be practically uniform, the loss of heat through the coated mains being comparatively small, and amounting only to a few degrees difference between the flow and return pipes in the engine-room.

III. COLD-WATER SUPPLY.

The system of cold-water pipes follows substantially the course of the hot-water pipes, with the exception that no circulation arrangements are provided. Wherever the cold-water mains and pipes are exposed to cold air, as is the case in the open basement underneath the ward block, they are covered with non-conducting composition in the same way as the hot-water pipes, in order to prevent them from suffering from frost.

IV. WATER STERILISERS.

In each of the operating-rooms is an apparatus for sterilising water for surgical purposes. The subject possesses considerable interest, but the author feels that he has already trespassed too far upon the time of the Meeting, and will only mention that the water for these purposes

is first warmed by means of a steam coil, and is then passed through a Berkefeld filter, whereby it has been proved to be absolutely deprived of every kind of microbe, and is thereby rendered innocuous for surgical use. The temperature is regulated with the greatest facility.

V. THE LAUNDRY [fig. 13].

The laundry was carefully designed so that the articles to be cleansed should progress through all the consecutive stages of treatment without being carried over the same ground twice. The ordinary type of machinery is employed. The exhaust steam from the laundry engine is used to heat the drying closet and water for the washhouse. A fan draws air from the ironing room, forces it through the heating coils of the drying closet, and thence into the washhouse, upon the steamy atmosphere of which it has a beneficial effect.

VI. ELECTRIC LIGHTING.

Electricity for lighting the hospital is supplied from the town mains, and is delivered into the hospital on the 3-wire system, at a pressure of 440 volts between the outers. The meters, the main switch, and the distributing boards are placed in a room in the basement. The system of wiring is that which is now well known and generally used, but which the author believes he was the first to use, namely, placing a suitable number of fuse-boxes about the building; using the same-sized sub-mains throughout for supplying the fuse-boxes; using the same-sized fuses in all the fuse-boxes; placing not more than five 60-watt lamps on each fuse for 100 volts, or eight lamps on each fuse for 220 volts; and using the same-sized lamp leads throughout the whole building. The total number of 16-c.p. lamps, or equivalent, installed in the establishment, is about 1,100.

DISCUSSION OF THE FOREGOING PAPERS.

The President, Mr. Aston Webb, R.A., F.S.A., in the Chair.

Sir JOHN HOLDER, Bart., said he had been asked—and he rose with great pleasure—to propose a very hearty vote of thanks to Mr. Henman and Mr. Lea for their interesting and instructive descriptions of this unique and novel hospital. It was his privilege to be chairman of the Building Committee of the General Hospital in Birmingham which had been designed and built by Mr. Henman. When they decided to build that hospital they had a limited competition, and they had as their adviser a gentleman whose portrait hung in that room, viz. Mr. Alfred Waterhouse. It had been a great pleasure to him to be connected with Mr. Waterhouse—a more charming man he had never met. That competition took place, and Mr. Henman's plans were far superior to any of the others sent in. They had given him the work, and had every reason to be proud of what he had accomplished in connection with the General Hospital. The building was designed for a system of natural ventilation. After the plans had been accepted, a friend of his—a civil engineer in Birmingham—wrote and asked him to go and see a hospital that was ventilated on Mr. Key's plenum system at Glasgow. As he was very much against the plenum system, he simply acknowledged the letter and took no more notice of it. Then he received another very strong letter begging him to go and see the hospital. He went, and took Mr. Henman with him; and when he (the speaker) saw the ventilation of the hospital he became a convert to the system. Returning to Birmingham he called a meeting of the committee, and afterwards took up to Glasgow three or four honorary surgeons and physicians and some laymen, and they were even more pleased with the system than he was. What convinced him more than anything else was that the second time he went to Glasgow, on a dark, muggy, rainy day in November, after they had been over the hospital, Mr. Key showed the party over some Board schools, with about 1,200 children, where the system was installed. Generally the atmosphere of such places, with children from a very poor neighbourhood, was most disagreeable, especially on a wet, muggy day. He was, however, greatly struck with the sweetness of the atmosphere of these schools. There was no smell at all, although the children had been there for two or three hours. He asked one of the mistresses if she ever had teacher's headache. No; she used to

have it at her old school, she said, but never at the present one. The master said he liked the ventilation immensely; the only fault he found with it was that between 11 and 12 o'clock in the day he became so hungry that he wanted his lunch! Although they had nothing to complain of in the natural system of ventilation Mr. Henman had provided, they decided to change it for Mr. Key's system of plenum ventilation, and they were very pleased indeed that they had done so. On the coldest days of winter the lowest temperature he could find in any part of the hospital had been 59°, when they had 14° of frost outside. On the hottest days in summer, with the temperature at 84° in the shade, the highest temperature he had found in the hospital was about 68° or 69°. Patients and nurses were breathing fresh air the whole time. If a case of measles or scarlet fever broke out in a ward, they rarely had to close the ward. There was so little contamination; one patient did not breathe emanations from another, and the foul air was carried straight away. Before the Birmingham hospital was built the Johns Hopkins Hospital in Baltimore was always held up to them as a model. When he was in America he went over the Johns Hopkins Hospital, and, though it was a fine hospital, it was nothing to compare with theirs in Birmingham. He had also gone over the new hospital of the McGill University at Montreal, and the new Presbyterian Hospital in New York—the latter quite a modern building—and he was still more pleased with their own at Birmingham after seeing these. From the time Mr. Henman sent in his competition drawings to the present time there was not a single room, passage, or door altered in the whole main block of the building. The late Sir William McCormack, who visited it, said he had been over hospitals in England, and almost everywhere else in Europe, and he had never seen a finer or a better equipped one than that at Birmingham. The building is on the pavilion plan, heated and ventilated on Mr. Key's system, perfected by Mr. Henman. He was glad to find, however, that Mr. Henman, and Mr. Henry Lea particularly, had gone in for a much better system of heating and ventilation. At the Birmingham Hospital there were four stations for the intake of air and two fans to each place, the fans being driven by electricity. They got electric power at a low rate, but the cost of driving the fans was £600 a year. With only one station at Belfast they were able to economise greatly the upkeep of the heating and ventilating arrangements.

Dr. CHRISTOPHER CHILDS, who was asked by the President to give them his views, said he had not come prepared to speak, and if he did, he was afraid he must strike a discordant note; but a discordant note in a discussion was perhaps rather a necessity. He should like to have heard a little more from Mr. Henman about the question of inlets and outlets. He did not pretend to be an expert, but he had given what time he could to the study of the plenum system, and was strongly convinced that it was the best method they had for ventilating crowded buildings of any kind. He had, however, come across a great many defects with regard to the position and the relative size and shape of the inlets and outlets; he had not had an opportunity himself, at any rate, of finding out that any principles had been laid down with regard to those details, which were certainly most important, because in the ventilating of a room or building they had not merely to supply a sufficient quantity of proper air, but must distribute that air in such a way that each inmate should have his proper share of unpolluted atmosphere. Those who had had opportunities of studying various systems of plenum ventilation in schools or elsewhere found that there was frequently a distinct want of method; that there were many defects by which the air was either short-circuited in some cases, or distributed to certain parts; while in a considerable amount of cubic space the air was quite stagnant. He hoped Mr. Henman might be able from his large experience, and especially from the experience he had acquired in this new hospital which they all admired so much, to give them some hints as to these details. As a physician, however, he must throw in his discordant note. We all recognised the necessity of having a sufficient quantity of pure air, and it was the custom to gauge the purity of that air by certain phenomena: the amount of carbon dioxide, the amount of organic matter, and also, in addition to that, the proportion of microbes in the atmosphere. They knew that if air which was being respired by human beings contained too much carbon dioxide, or too much organic matter, that air was not to their benefit. These conditions could be gauged by means of the chemist's balance: they could gauge also the number of microbes by bacteriological methods with the aid of the microscope. But there was one quality of air they knew very little about, viz. the quality generally ascribed to what was called "fresh air." Did the plenum system contain that invigorating essence which they recognised as given by fresh air? To his mind that was the one thing wanting in the air provided in hospitals by the plenum system. The benefit derived when they threw open the window in a close room and got the fresh air from outside was no imagination. They saw it illustrated in the effects of exercise; for instance, after riding on a bicycle or a motor. Or, again, if one were in a valley or, on a rather close day, below the brow of a hill, if there were no movement of the air, everything was an effort to one—there was a want of energy, which was supplied the moment one surmounted the brow of the hill

and encountered the breeze. What was the difference? He did not think this had been sufficiently considered in estimating the benefit of ventilation. The difference apparently was due in some way to the movement of air over the body; and one would like to point out that in what they called natural ventilation they asked for 3,000 cubic feet per individual when they were within four walls under a roof, and they were very lucky if they got it. But in the open air on a moderately calm day they had not 3,000, but 300,000 cubic feet passing over the body; and there was some effect that they had not yet gauged, due to this air moving over them. That this was not fanciful was again shown by the wonderful effects produced by the open-air method recently introduced in the treatment of phthisis. It was true that the plenum ventilation did away with draughts and produced a uniform temperature; it was true that they could control the variations of the air. But was that the best thing for the patients? Was not that variation of air from time to time a stimulus to patients which conduced to their welfare? Anyone who had tried the fresh-air treatment, as opposed to the closed-window treatment, would tell them how much more free they had been from colds and catarrh. Consumptive patients, when admitted to the open-air treatment, and even to draughts, felt better than when they were within the closed walls of a room. Before they said absolutely that the plenum system was the best for hospital ventilation, those things ought not to be lost sight of.

Mr. A. SAXON SNELL [*F.*] said that the subject was of extreme importance, in that the advocates of the plenum ventilation were introducing to the public generally, and to architects, a system which had the great attraction of something novel and something complicated. Those who felt that the plenum system was a huge mistake should do their best to have it well argued out; and he suggested that as the hour was so late the debate should be adjourned to a future occasion.

Mr. H. T. HARE [*F.*] seconded the proposal to adjourn, as further discussion he thought would be instructive and useful.

THE PRESIDENT said that they had been extremely interested in these papers; the subject must appeal to all architects, and to those who were engaged in the erection of buildings of a large and public character, to which he supposed the plenum ventilation must be confined. If they could arrange for another meeting they would do so; but it was always a little difficult to get the same audience together, and to pick up the threads of a discussion where it had been left. He had been very much interested in the plenum system, and especially in Mr. Henman's novel and bold effort to meet the difficulties which a long extended hospital undoubtedly presented to many people. They all knew examples of hospitals which were extended to such a length that supervision of them became almost impossible. Mr. Henman's idea of bringing the wards all together on the one floor, and under the easy control of the staff, must be an enormous advantage in hospital planning. The question was whether this plenum system would sufficiently ventilate the wards—that he understood to be the main difficulty—and whether the closing up would allow of their being properly lighted. He had not seen the hospital, but only the photographs shown that evening; and one naturally felt how bold a scheme it was to light these wards from the top. But with regard to the ventilation system, and with regard to what Dr. Childs had said of the advantage of passing through air, the plenum system in a building seemed to him to have the advantage at any rate of passing air over the occupants. One could not, of course, in bed pass through the air, but by the plenum system the air passed over one more rapidly than by any system of heating by radiators or pipes; and one advantage of moving the air under mechanical propulsion was, it enabled them to some extent to control and regulate the amount of air passing in and out of any particular room. As regards the disadvantages of the system, he agreed that the more they could talk the matter over the better, and they would endeavour to have another meeting so as to have it well thrashed out. He was sure they were all pleased to see Mr. Henman among them that evening. He (the President) was with him in the Class of Design at the Architectural Association a great many years ago, and he had often seen him since. He had also had the pleasure of working with Mr. Lea, on and off, for a good many years too; so that they were both old friends of his. He knew they would all join in giving a very hearty vote of thanks to both of them for bringing before the Meeting this very novel and original arrangement. It was what the Institute especially invited people to do; and when anyone was bold enough to attempt anything fresh, if he would be good enough to bring it to the Institute, and explain it, they were under an exceptional debt of gratitude to him for doing it.

Mr. HENMAN said that at that late hour he could do little more than thank the Meeting for the kind reception accorded to his Paper. It was impossible to fully discuss "plenum" ventilation in the time at their disposal; he thought Dr. Childs had not really investigated the actual effect of it on patients in hospital wards: he had expressed fears but given no proof that there was real foundation for them. With "plenum" ventilation efficiently applied, as at the General Hospital, Birmingham, and at the Royal Victoria Hospital, Belfast, the atmosphere of the wards was equally fresh and pure throughout the twenty-four hours of the day and night. That was a severe test,

and was absolutely attained. [Sir JOHN HOLDER: Hear, hear.] In visiting existing hospitals he (Mr. Henman) invariably asked about the ventilation of wards, and found that even in the daytime, with windows open, they were not always so fresh as those to which he had referred. Frequently he had been informed that at night, when the windows could not be so freely opened, the ventilation was bad, and that at times the state of the atmosphere was intolerable. The reason was simple. Writers on hospitals had unfortunately laid it down that 3,000 feet of air per patient per hour sufficed (or, with a cubical capacity of 1,000 feet, a change of air only three times per hour); but with ordinary haphazard methods even that small amount of change only took place when there was ample movement of air outside, and the windows could be open; whereas an absolute and continuous change of air from seven to ten times per hour was secured in the buildings to which reference had been made.

Mr. HENRY LEA, in responding to the vote of thanks, said that if another meeting should be held he should be very pleased to attend, if desired, and to listen to all kinds of criticism that might be offered, and, so far as possible, to answer such criticism after he had heard it.

Mr. Henman sends the following further observations on the subject of plenum ventilation:—Having been favoured with a proof of the report of Dr. Childs' remarks, I have pleasure in confirming his statement that greater care should be exercised in respect to the relative size and position of the air inlets and outlets. Large quantities of air may be blown through without securing ventilation in all parts of a room, whether mechanical or natural means be employed. At the Birmingham Hospital the necessities of the pavilion arrangement of wards prevented such nicety of adjustment as we should have liked; but at Belfast there is a large inlet between every pair of beds alternately on opposite sides of the wards, and an outlet under *every* bed. Our experience is that the air supply is best regulated at the outlets: with inlets ever so large the volume of air passed in is only equal to that which is allowed to pass out; consequently, when air comes in through large openings, draughts are prevented provided the outlets are suitably regulated and well distributed, and every portion of the room will be properly ventilated. Proof of this is that thermometers placed in different parts register the same temperature. Such is rarely the case when any but plenum ventilation is employed. In "sounding a discordant note" I fear Dr. Childs rather missed the mark in connection with what he said about fresh air in the open. People capable of climbing hills, riding cycles and motors, are not hospital patients, but generally individuals in reasonably good health; yet take any number of such, and you will find few of them will agree as to the quality of air which suits them best or the amount of air movement which is preferred. Then his statement is most reckless "that in the open, on a moderately calm day, they had not 3,000 but 300,000 cubic feet passing over the body" (per hour, I presume he intended to say, because 3,000 feet per hour is the orthodox—but inadequate—supply for within doors). Three hundred thousand feet per hour passing over the body would be at the rate of 83 feet per second, or nearly a mile a minute; only the most robust could stand it; it would be death to most hospital patients. Dr. Childs also misses important points in connection with the open-air treatment. Does he not know that for patients at rest all sorts of contrivances are produced to guard them from the action of winds and draughts; that warm clothing is advised for the same purpose; that in rooms, even with windows fully open, air stagnates more or less in proportion to the want of power of wind outside? Where, then, is the difference between trusting to the power of wind in one case and a mechanical power in another? Why, simply in this, that one is uncertain and intermittent, at times too strong, at other times too weak; but mechanism can be regulated and made to work continuously. Once determine what suitable change of air is required, then it can with ease be secured; it is the same air that is moved, whether by wind or mechanism. A hand-fan is employed frequently in the open; why should not a similar but more powerful mechanism be employed for within doors?

Discussion may clear away some prejudices, but until the opponents of ventilation by mechanical means approach the subject in a scientific manner time is simply wasted when only vague surmises and reckless statements are set forth. As I implied in the introductory remarks of my Paper, the principle has been conceded, and we acknowledge failures have taken place; therefore our object is to show that nevertheless success is attainable, because over six years' experience can be pointed to as proof. The buildings are there, and every week patients pass through the wards as quickly as, if not more quickly than elsewhere, having spent the time of compulsory confinement in comfort, and generally leaving in good health and spirits. I often think of Stephenson's critics regarding the dangers of railway travelling; and when he was asked what would be the effect of a cow getting on the lines his reply was, "It would be a bad thing for the cow." Improvement in details has overcome all early fears in connection with railways; so I believe it will in connection with "plenum" ventilation.

WILLIAM HENMAN.

9, CONDUIT STREET, LONDON, W., *19th Dec.* 1903.

CHRONICLE.

Test of an Armoured Concrete Column [p. 48].

Messrs. W. CUBITT & Co. write :—

With reference to Mr. Dunn's article in the number of the Institute JOURNAL for 21st November on the Test of an Armoured Concrete Column, we have been told that several architects are under the impression that the safe load of $\frac{130}{3}$ tons per square foot mentioned on p. 50 of the JOURNAL represents the safe load per square foot for any armoured concrete column.

May we be allowed to point out that the strength of an armoured concrete column varies with the percentage of metal used in the reinforcement? The column tested by Mr. Dunn was reinforced with ·414 per cent. of metal in the vertical rods; we frequently use columns reinforced with 2, 3, 4, or more per cent. of metal where greater strength is required. Quite recently we have constructed columns, on the Hennebique patent system of armoured concrete, that carry a safe load of 110 tons per square foot.

Building By-laws Reform.

The Council of the Building By-laws Reform Association have appointed a committee to consider and report on the amendments needed in the existing building by laws. The committee consists of the following members :—Mr. W. M. Acworth, Lord Robert Cecil, Mr. A. H. Clough, Mr. A. Graham, Mr. W. Henman [*F.*], Mr. Mark H. Judge, Mr. E. L. Lutyens, Mr. Arthur Newbold, Dr. G. V. Poore, Mr. H. A. Powell, Mr. Lacy W. Ridge [*F.*], Mr. R. W. Schultz, Mr. J. St.-Loe Strachey, Mr. E. D. Till, Mr. Thackeray Turner, Mr. C. Turnor, Mr. H. G. Willink, the Hon. Percy Wyndham, together with the chairman and honorary secretary. For the purpose of securing some relief from the more oppressive of the by-laws now in force in rural districts, the committee is to approach the Local Government Board and endeavour to secure their publishing a new set of model by-laws for these districts, embodying amendments which the committee may suggest to the desired end. District councils are then to be urged to amend existing by-laws accordingly.

The Committee is to prepare draft building by-laws carrying out the recommendations that "the by-laws should lay down principles," and that "each by-law should provide that, unless the principle it enunciates is otherwise given effect to, to the satisfaction of the local authority, it shall be considered to be given effect to if the requirements set out in the schedule to the by-law are complied with."

As soon as practicable the by-laws of urban districts are to be dealt with in like manner.

Members of the Association are requested to inform the By-laws Committee of any cases of hardship under existing by-laws, and they are asked to make the Association known to their friends in order that the number of members may be increased as much as possible before the annual meeting next February.

Dr. Evans's Explorations at Knossos.

At a recent meeting of the Hellenic Society Dr. Arthur Evans gave some account of "The Last Campaign at Knossos." During the past season he had expected that the work would be finished in a month or two, but there were unexpected developments, and he lighted on the remains of outlying buildings adjacent to the palace. These proved to have been structures of an earlier period, and constituted interesting additions to the first discoveries. There were disclosed one or two houses apparently of high officials of the court. On the north-east side of the house there was a characteristic room with a square pillar in the middle. There was also a window in the outer wall, and on the portals was discerned a beautiful fresco of lilies. There was also a spiral column of porphyry or similar material, and close at hand a wall painting of olive or myrtle sprays. At the back he found a columnar chamber, on the floor of which was a quantity of curious pottery which appeared to have been dedicated to sacred purposes. The house itself, with its double colonnade, was a kind of miniature of the palace. On the north-east of the palace there was a sort of royal villa. The side of the hill was tunnelled, and going through the passage he struck upon a stone staircase from which two smaller staircases branched off. More searching investigation disclosed a perfect Minoan house. The main entrance was from a terrace above, and traces of upper stories were discernible. There was a double doorway which led direct into the largest hall of the palace. This system of open halls which might be shut off at will secured coolness in summer and warmth in winter. One of the most remarkable features was a recess containing the remains of a throne—indeed, in these early times there were many of the features which marked a Christian basilica. An elaborate system of lighting had apparently been devised. There were other rooms also with a pillar in the centre. The

roof was made of timber more massive and solid than any now found in the island. Many interesting objects were found in the house, among them vases of a wholly different character from those in the palace itself, and wall paintings of designs like those of the vases. Two of the latter were specially beautiful, with papyrus relief forming good examples of the later palace style. The house itself was built against the rock, and in it there was a system of corridors, light wells, and other arrangements for excluding the damp. There were marked evidences of the careful attention bestowed on sanitation by Minoan builders. During the season pits were sunk, and they came to a lower pavement and a large stepped area. The remains were in a decayed condition, but the line of the outer wall could be made out and the general dimensions clearly ascertained. The stepped area was, it would seem, a primitive theatre, though it was hard to conjecture the character of the performances. Near at hand were very singular miniature frescoes of gaily dressed women. Close by was a building of great complexity of wall, and on the ground were many objects illustrating the local cult of the double axe. A group of fine bronze vessels was also found with a foliated design and reliefs of an Egyptian style not unlike those of Thothmes III. The ornament was of a lotus and papyrus development. On a lower level were vases of an earlier period, which might perhaps be assigned to the third millennium B.C., when Crete was in communication with the Egypt of the twelfth dynasty. This might be termed the middle Minoan period, and the work was of elaborately beautiful design. There was also a deposit of earlier times, which might be called Early Minoan, ranging from the sixth to the eleventh dynasties of Egypt. The ware was incised, and appeared to fit on with late Neolithic work. There was altogether a depth of about 25 feet of deposit at Knossos of different periods. The cists of the earlier period appeared to have been closed, probably after some revolutionary movement. It might be stated with reasonable probability that the latest part of the palace was of the date of 1500 B.C. Many of the objects appeared to be religious emblems, and the goddess and the lions frequently appeared. These were found in what might be presumed to have been a sanctuary disclosing the relics of a shrine. The pottery was like the early work of Melos. The religious character was found on many of the seal impressions on which the goddess and the lions were seen, and snakes held in the hands. It was a surprise to come upon faïence figures of women in a strange costume beautifully embroidered. Votive rites with snakes were figured in this faïence, which showed the extraordinary perfection of the art of the middle period. There was also a very remarkable faïence relief of a wild goat and kids. The great surprise of the excavation was the discovery of what seemed to have been the central object of the cult, in the form of a marble cross of orthodox Greek shape. Other pre-Christian survivals of this symbol seemed to fit on this Minoan cult. The Italian mission had discovered a smaller palace and sarcophagus, which illustrated the cult of the double axe. The inference was that the kings, like Minos himself, had a sacerdotal character—were priests as well as kings.

Sir James Knowles [*F.*].

The congratulations of the Institute will be cordially tendered to its distinguished Fellow the new Knight, Sir James Knowles, whom the King a few days ago invested also as Knight Commander of the Royal Victorian Order. Sir James, founder, proprietor, and editor of the *Nineteenth Century*, is seventy-two years of age, and has been a member of the Institute over fifty years, joining as Associate in 1851 and proceeding to the Fellowship in 1876. His work as an architect includes the late Lord Tennyson's Surrey House, Kensington House, the Thatched House Club, the public garden and fountain in Leicester Square, and some churches. He has written a good deal from his earliest years, and originated the Metaphysical Society. In 1870 he succeeded Dean Alford as editor of the *Contemporary Review*. Seven years later he founded the *Nineteenth*, a conspicuous success from its first number, the introductory sonnet being written by the editor's friend and constant companion, Lord Tennyson.

Royal Academy £200 Studentship.

Mr. Lionel Upperton Grace, a Student of the Institute and winner of the Grissell Gold Medal 1902, has been awarded the Royal Academy Gold Medal and £200 Travelling Studentship for a design for a Domed Church.

Reinstatement.

At the meeting of the Council on Monday the 14th inst. Mr. John Frederick Fogerty, B.E., was reinstated as an Associate of the Institute.

The late Charles Fowler [*F.*].

Mr. Charles Fowler, who died on the 8th inst. aged eighty years, was elected Associate of the Institute in 1851 and Fellow in 1862. Until later years he had been an active worker for the Institute, serving for some years the office of Chairman of the Statutory Board of Examiners, and also as a member of the Council and of various committees. The President made feeling allusion to his death at the General Meeting last Monday, and a resolution was passed that a message of condolence be sent on behalf of the Institute to his family.

Mr. Henry Lovegrove [*A.*] kindly contributes the following particulars of his career:—

Charles Fowler was a son of the Charles Fowler who was for some years one of the Hon. Secretaries of the Institute, and architect for Hungerford and Covent Garden Markets in London, Exeter Market, and Devon County Lunatic Asylum. After he (the father) had retired from practice he lived at Great Marlow, and was buried near the river.

Mr. Charles Fowler, jun., studied under his father, and was for some time with an eminent architect in Germany. He was a good linguist, especially in German and French, and a most accomplished draughtsman, as some sketches in the Architectural Publication Society's Dictionary will show. After his travels were completed he commenced practice, and gave very able assistance to his friend Sir Digby Wyatt in the designing of Paddington Station and a large building for the Government on the south side of the Thames. In 1854 he was appointed District Surveyor of St. Giles and Bloomsbury in succession to Mr. Geo. Pownall, and in 1871 was promoted to Shoreditch, which he held for twenty-one years, and resigned on the 7th November 1892. He was for a number of years surveyor to the Portland Estate, where he succeeded Mr. H. Baker, and the new building schemes were planned by him. He was at one time surveyor to the Wax Chandlers' Company and to several estates. As architect he designed several blocks of model dwellings, the Phœnix P. H., Norton Folgate, and the Peacock P. H., Maiden Lane, Izant's Restaurant, Middlesex Music Hall, and a large timber store in the Hackney Road; National Schools, Hoddesdon, Herts; and many business premises, new houses, and alterations. In 1851 he wrote most of the description of the Great Exhibition for Messrs. Cassell's *Illustrated Exhibitor*. He was for years Honorary Secretary of the Foreign Architectural Book Society (a social reading club), and also of the District Surveyors' Association. The latter body he afterwards served as President. A more accomplished architect or kindly gentleman it would be difficult to find. Since 1868, when I first made his acquaintance, I have received from him many acts of kindness and consideration, and am proud to think that of his many old assistants I hold two of his appointments. On his retirement about a year ago he went to live at Abbotsleigh, Farnborough, Hants, where he died.

The late Mr. N. Y. A. Wales [*F.*].

It is with much regret that I have to record the loss of Mr. Nathaniel Young Armstrong Wales [elected *Fellow* 1901], of Dunedin, N.Z., who died on the 3rd November. Mr. Wales was a man of many parts, and filled them all well. As an architect his work was good and without affectation, and many of the larger buildings of Dunedin are his design. His personal character and disposition were such as to win the regard of all who knew him. Outside his profession he was a leading citizen, and for over forty years he had taken part in forming and helping forward many of the movements incidental to a new and vigorous colony. As far back as 1862 he joined the Volunteers and became colonel of the 1st Battalion of the Otago Rifles; he was also a lieutenant-colonel in the New Zealand Militia. He had been a member of the City Council and Mayor of Dunedin, was a member of the Assembly when the abolition of provinces (in New Zealand) took place in 1872, was a member and afterwards Chairman of the Otago Harbour Board, and held many other offices of perhaps not quite so public a character. In bringing this short notice to a close I will quote the following from the Otago *Daily Times*:—"Mr. Wales will long be remembered by a wide circle of old friends and acquaintances, who will feel that Dunedin is the poorer by the loss of an estimable citizen, and one whose career a younger generation might do worse than try to emulate."

F. DE J. CLERE [*F.*],
Hon. Sec. R.I.B.A. for New Zealand.

MINUTES. IV.

At the Fourth General Meeting (Ordinary) of the Session 1903-1904, held Monday, 14th December 1903, at 8 p.m.—Present: Mr. Aston Webb, R.A., *President*, in the Chair, 38 Fellows (including 9 members of the Council), 47 Associates (including 3 members of the Council), and numerous visitors: the Minutes of the meeting held 30th November [p. 82] were taken as read and signed as correct.

The following Associates attending for the first time since their election were formally admitted by the President and signed the Register—viz. Guy Church, Percy Boothroyd Dannatt, Archibald Lawrence Holder, Ernest Martin Joseph, and Edwin Paul Wheeler.

The President announced the decease of Charles Fowler [*Associate* 1851, *Fellow* 1862], and, having referred to his services to the Institute, moved, and it was thereupon resolved, that the regrets of the Institute be recorded on the Minutes, and that a message of sympathy and condolence be sent to his family.

The decease was also announced of Nathaniel Young Armstrong Wales [*Fellow* 1901], of Dunedin, N.Z., and William Warlow Gwyther [*Fellow* 1880].

Papers on THE ROYAL VICTORIA HOSPITAL, BELFAST: ITS INCEPTION, DESIGN, AND EQUIPMENT having been read by Messrs. William Henman [*F.*] and Henry Lea, M.Inst.C.E., some remarks were made by Sir John Holder, Dr. Childs, and the President, and a vote of thanks was passed to the authors by acclamation and briefly responded to.

As owing to the lateness of the hour there was no time for discussion of the Papers, a motion for adjournment was made by Mr. A. Saxon Snell [*F.*] and seconded by Mr. H. T. Hare [*F.*], and the President promised that a meeting for the purpose should be arranged if possible.

The proceedings then closed, and the Meeting separated at 10.30 p.m.